ELECTRICITY AS A MOTIVE POWER ON TRUNK LINES.

BY C. L. DE MURALT.

In an article on this subject which appeared in the December number of this REVIEW, Mr. Cornelius Vanderbilt, after a very careful study of the situation, came to the conclusion that, while it is possible from an engineering standpoint to adopt electricity as the motive power for our railways, yet, regarded from the financial point of view, the change is not possible. Following very nearly the same train of thought one may, however, easily come to the opposite conclusion, viz., that it would be a great advantage both from an engineering and a financial standpoint to have all trains propelled by electricity, and it is the object of this paper to set forth this side of the question.

Starting at the same point as Mr. Vanderbilt we find that, from the standpoint of those in charge of the railways, every dollar spent on electric equipment must be considered as an excess charge against the electric railway, and, as such, the expenditure will only be warranted if the saving in transportation expenses and in depreciation of plant, or the increase of business, will insure a material dividend on the increased investment. Let us, with Mr. Vanderbilt, dismiss from the beginning all considerations as to the convenience and comfort of passengers, for the reason that, although better facilities in this respect often pay for themselves, freight business is at present the principal source of revenue, and therefore of more interest to the railroad manager. We thus find that, if electricity is to be adopted at all, it ought to provide a more economical method of transportation. We will therefore have to look carefully into the question of operating expenses, and in doing this it will probably be best to adhere to the five points raised by Mr. Vanderbilt for purposes of comparison

between the two systems: first, cost of a unit amount of fuel; second, amount of useful work realized from this fuel at the driving wheels; third, cost of conducting transportation or handling trains; fourth, cost of repairs to machinery; fifth, cost of repairs to roadway. If our investigation is to lead to tangible conclusions, it will be necessary to go somewhat more into detail than did Mr. Vanderbilt, whose article treats the subject, as he says himself, only in a very general way. It will be necessary, above all, to introduce some figures, though we shall try to limit these to the minimum.

In regard to the first point, we will agree that the cost of fuel should be taken as being equal on any given road for both systems; although, in some cases electric central stations might be able to make use of a cheaper coal or oil than would be possible or advisable on locomotives.

Passing on to the second point, the amount of useful work realized at the driving wheels, we find that a convenient way of comparing the two systems in this respect will be to determine in each case the cost of motive power per train-mile. The following two trains may be taken as representing fairly typical conditions: an average passenger train, weighing between 200 and 250 tons, running at an average speed of thirty-five miles an hour, and an average freight-train, of about 800 tons, making about fifteen miles an hour. We shall therefore try to find out the cost under either system of hauling these trains one mile.

Let us suppose for a moment that, in the case of the electric system, the railroad company does not build its own central stations, but, as is often done in street railway practice, buys the electric current from electric power companies, whose plants are conveniently situated along the road. With a modern alternating current power transmission, it will be possible to supply one hundred and more miles of track from one central station; the latter will therefore be of considerable size, which will permit the installation of large generating units, with the combined advantage of comparatively low first cost and high working efficiency. Such a station would be able to sell the horse-power hour, taken at its switchboard, at about half a cent. The electric energy thus obtained will then have to be distributed by the railroad company along its track to the various locomotives, and there transformed by the electric motors into mechanical energy.

In the present state of the art, the average efficiency of such a transmission system may be taken at about sixty per cent., which means that, for each horse-power hour required at the axle of the locomotive, one and two-thirds horse-power hours will have to be produced at the central station. The cost of one horse-power hour at the drivers thus works out to be about eight-tenths of a cent. The above-mentioned passenger train would take about eight horse-power hours per mile, the freight train about seventeen horse-power hours. The cost of motive power per train-mile would therefore be in the neighborhood of six and a half cents for the average passenger-train and thirteen and a half cents for the average freight-train if the electric energy is obtained from a steam central station.

In the case of a hydro-electric plant the figures are somewhat different. Most central stations of this kind are able to sell the horse-power at about twenty dollars per year, some even as low as ten dollars. Assuming for the distributing system the same efficiency as above, this would bring the cost of one horse-power hour delivered at the drivers to something between one quarter and one half of a cent. The cost of motive power per train-mile would thus be four cents or less for the average passenger-train, and not more than eight and one-half cents for the average freight-train.

Unfortunately, the performance of the steam locomotive cannot as readily be expressed in figures, as the coal consumption per train-mile varies within wide limits. From the reports of a great number of roads it is, however, evident that the average coal consumption for all trains of any one road will be considerably over one hundred pounds per mile in most cases. A very conservative estimate will place the average coal consumption of a passenger-train, operated under the conditions mentioned above, at about sixty pounds per mile, and of a freight-train as above at one hundred and fifty pounds. With coal at two dollars per ton, or one-tenth of one cent per pound, this brings the average cost of motive power per train-mile to about six cents for an average passenger-train, and about fifteen cents for an average freight-train.

We thus are led to the conclusion that what Mr. Vanderbilt admits as a possibility is really a fact. The motive-power obtained by the double conversion of steam or water-power into

electricity and back into mechanical-power by means of electric motors, is not any more expensive than the motive-power obtained by the single conversion in the direct-acting steam-engine of the present-day locomotive. As a matter of fact, the electrical energy will in most cases turn out to be the cheaper of the two. We shall, however, not claim any superiority in this respect, but take note only of the fact that, when calculating the cost of the electric horse-power hour, the central station plant was supposed to be owned by an outside party. The price arrived at does, therefore, already include the operating expenses of the plant, as well as interest and depreciation on the capital invested therein; and the only additional investment which the railroad company would be called upon to make would be the capital required to install the electrical distributing system along its track, assuming with Mr. Vanderbilt the cost of electric-locomotives to be the same as that of steam-locomotives, and the other rolling equipment to be identical for either system. That a very fair return can be paid on this amount by the savings effected in operating expenses through the adoption of electricity as motive power, will be shown in the following considerations.

We are thus brought to the third point of comparison, the cost of conducting transportation or handling trains. The total expense classified under this heading is made up of the following items: cost of motive-power (fuel); water supply to locomotives; oil, waste and other supplies; wages of engineers, firemen, wipers and turners; wages of other trainmen; wages of switchmen, flagmen and watchmen; all other expenses, such as wages of station-agents, train-dispatchers, station-supplies, etc. Of these different items, only the first four would be seriously affected by the adoption of electricity, whilst the wages of trainmen other than engineers, firemen or roundhouse-men, the wages of switchmen, flagmen and watchmen and all other expenses may be taken as being practically the same in both cases.

We have seen above that the cost of one unit of energy expended on the track may be called equal for electric and steam-locomotives; but this does not necessarily mean that the total cost of motive power will also be the same in both cases. As a matter of fact, a handsome saving will be made on this account by the use of electricity, because the weight of an electric-locomotive required to haul a given load will be much less than that of a steam-

locomotive of equal capacity; because, also, the coal-consumption of a steam-locomotive is largely dependent on the skill with which it is handled, whilst this does not, or at least not to the same degree, affect the efficiency of the electric-locomotive; and, finally, because all switching-work will be performed much more cheaply. In the case of steam-engines, there is a great amount of dead weight hauled over the road in the form of tender, coal, and water. A locomotive weighing say sixty tons will have a tender weighing about thirty tons and probably ten tons more in coal and water, which makes a total of 100 tons, of which not much more than half rests on the drivers. Now, it is no exaggeration to say that an electric-locomotive of fifty tons only, having its total weight on the driving wheels, will do just as much useful work. If the locomotive were to be combined with one of the cars, either freight or passenger, as would probably be done in most cases, the reduction in weight would be still more obvious. In modern high-speed passenger service, the weight of the locomotive and tender often represents from thirty to forty per cent. of the entire train weight. With local passenger-trains this percentage will of course drop considerably, and it will be still lower in freight-trains. But, whatever it may be in any given case, it is evident that with an electric-locomotive it would be less than half as much; and, as any reduction in the train-weight represents just so much saved in motive power, the difference in the weight of the two kinds of locomotives will represent a saving in the cost of motive-power of at least five per cent.

It is not as easy to determine what influence the skill of the engineer and fireman has on the efficiency of the steam-locomotive. From actual records, it is quite certain that the coal-consumption may vary as much as ten to fifteen pounds per train-mile out of a total of perhaps 100 pounds. But it is difficult to draw an average; and, in order to be quite fair, it may therefore be better to drop this point entirely.

The saving effected in the operation of switching-engines is more easily expressed in figures. When we consider the character of work performed by these engines, which are in motion only a small part of the time, and yet have to keep a full head of steam on during the intervening periods of rest, we come to the conclusion that electric-locomotives, which draw energy from the station only when doing work, will be able to save at least thirty

per cent. of the energy used in this service. The coal consumed by switching-locomotives is on most roads between fifteen and twenty per cent. of that used by all the freight and passenger locomotives combined; and the saving under this item can thus be said to amount to another five per cent. of the total cost of coal. Add this to the five per cent. saved by the reduction of train-weight, and we find that the total cost of motive power will be reduced at least ten per cent. through the adoption of electricity.

As to water supply, electric-locomotives do not use any water and therefore the whole of this expense could be saved, and with it the water-cranes along the line, with all the trouble they cause during frost.

The cost of oil, waste, packing for stuffing-boxes, and similar supplies could be greatly reduced. There are probably twenty times as many parts that require lubrication on a steam-engine as on an electric-motor; and some of these parts, such as the cylinder, require a large amount of lubricant; then steam-locomotives are wiped off every day, electric-motors not once a week; no packing is required for electric-motors, etc. This item will therefore certainly be reduced fifty per cent.

The wages of engineers, firemen, wipers and turners will also allow of a considerable saving. In steam-railroad practice, each locomotive must be fitted with a steam engine, boiler, water-tank and coal-bunker, and these parts take up so much room that they must necessarily be made up in the form of a separate car on its own wheels, except in the case of small dummy-engines. In the case of the electric-locomotive, there is ample space on the trucks of a full-size steam railway-car, whether freight or passenger, to locate an electric-motor equipment of sufficient capacity to do the heaviest work required in railway service. It would, therefore, be well to combine the electric-locomotive with a baggage-car in the case of passenger-trains, and with a caboose in the case of freight-trains. Besides the reduction in weight thus obtained, it would then be possible to dispense entirely with the services of the fireman, as the baggage-master in the one case, and the conductor in the other, would take the place of second man on the locomotive for all cases of emergency. The number of roundhouse-men necessary for cleaning the electric-locomotive would certainly also be smaller, and a conservative estimate would therefore place the reduction in wages of enginemen at about twenty-five per cent.

If we now consider the fourth point, the cost of repairs to machinery, we agree with Mr. Vanderbilt that the cost of maintenance of the cars should be the same in either system; but we find ourselves of a different opinion when it comes to the maintenance of the locomotives. According to very good authorities, the cost of locomotive repairs may be apportioned to the various parts as follows: running gear, 20 per cent.; machinery, 30 per cent.; boilers, 20 per cent.; lagging of boilers and painting, 12 per cent.; smoke-box, etc., 5 per cent.; tender, 13 per cent. In the case of electric-locomotives, the last four items or just fifty per cent. of the total cost would entirely disappear, and it is certain that the amount of the other two would be greatly reduced, as the number of wearing parts is much smaller in an electric-motor than in a steam-engine. The saving in cost of locomotive repairs could, therefore, be safely assumed as fifty per cent., as this would in practice certainly be more than realized.

Coming finally to the fifth point and comparing the relative cost of repairs to roadway, we have on the one hand the effect of the unbalanced condition of the steam-locomotives upon the track, on the other hand the additional expense of keeping the electric contact line in good repair. Both are equally difficult to express in figures with any accuracy. In all probability, they will pretty nearly compensate one another; but, in any case, the difference resulting cannot be more than a small percentage of the total cost of repairs to roadway, which in turn makes up but a small portion of the total operating expenses. The difference will in no case exceed a fraction of one per cent. of the latter.

Let us now investigate the question of first cost. We have seen above that, with electric energy supplied by separate companies, and assuming the rolling-stock to cost the same in both cases, the electric system will nevertheless require an increased investment to pay for the electric distributing system along the line. It is evident that the interest on this investment represents a fixed charge per mile of track, which will have to be offset by a saving in operating expenses, and this can of course only be done if the traffic over the road has a certain density. The latter condition, however, is met much more often than is generally supposed; and that our large trunk-line systems do not make an exception in this respect, will be seen by examining one or two cases a little more closely.

Let us take for instance the Pennsylvania and the New York Central & Hudson River roads. The former operated last year a total of 3,670 miles of road, the latter a total of 3,320 miles. With an alternating current high-potential system, the electric equipment of the line would not cost more than $6,000 to $7,000 per mile, including second, third and fourth tracks and sidings, or a total of $25,690,000 for the Pennsylvania, and $23,240,000 for the New York Central. If we count ten per cent. for interest, sinking fund, etc., this would represent an annual charge of $2,569,000 in the one case, and $2,324,000 in the other.

The operating expenses for these two roads during the last year were made up as follows:

	Pennsylvania.	N. Y. Central.
Fuel for locomotives (motive power)	$6,000,133.94	$4,635,877.09
Water for locomotives	335,286.00	295,582.77
Other supplies for locomotives	382,548.12	334,672.56
Wages of engineers, firemen, and round-house-men	5,716,847.83	4,829,442.54
Wages of other trainmen	4,442,127.34	2,991,334.66
Wages of switchmen, flagmen, and watchmen	3,900,427.49	2,511,552.06
Other expenses for conducting transportation	14,540,541.88	11,607,537.54
Repairs to locomotives	4,412,983.29	3,608,971.89
Repairs to other equipment	10,674,725.61	5,661,991.79
Repairs to roadbed	8,541,935.48	6,145,341.10
Repairs to structures	4,122,017.98	2,454,690.96
General expenses	1,858,319.09	1,786,494.17
Grand total	$64,927,894.05	$46,863,489.13

Applying the figures found during the course of our investigation, this list will allow of the following reductions if electricity were adopted as motive power:

Fuel, 10 per cent., or	$600,013.39	$463,587.71
Water, saved entirely	335,286.00	295,582.77
Other supplies, 50 per cent	191,274.06	167,336.28
Wages to engineers, etc., 25 per cent.	1,429,211.96	1,207,360.63
Repairs to locomotives, 50 per cent.	2,206,491.65	1,804,485.95
Total amount saved	$4,762,277.06	$3,938,353.34

In the case of either road, the amount saved would be almost double the amount necessary to pay a handsome return on the additional investment, and it will be remembered that we have been extremely conservative in every part of our estimate.

Similar figures apply to most of our large railroads; and we thus come to the conclusion that it is not in the cost of fuel alone

that we may expect to find the economy of the electric system. Some of the other items taken together add up to a very important amount, and will cause the operating expenses of most of our roads to be smaller by using electricity than by using steam, without mentioning at all the advantages of increased comfort to passengers, and the possibility of greater speed should this be desired.

If water-power can be used for producing electricity, that will simply mean an additional advantage. In that case, the cost of motive power will be greatly reduced, and the saving thus effected will amount to at least one-third of the total amount now spent for fuel, and often to a great deal more. For a railroad like the New York Central, capable of supplying practically its entire system from the water-power of Niagara Falls, the upper Hudson and the St. Lawrence, this would represent an additional saving of more than one and a half million dollars yearly.

Of course, even with these convincing figures it would not do to imagine that a complete trunk-line system of several thousand miles of road could be converted from steam to electric traction all at once. Yet there is no reason whatever why electricity should not be adopted immediately on those sections of the road where the saving is most apparent. Instead of spending each year large amounts for additional steam-engines, as has to be done at present, these amounts could be used for gradually acquiring all the necessary electric-locomotives; and, in the mean time, the steam-locomotives thus rendered superfluous on the sections operated electrically could be used to complete the rolling-stock of the sections still employing steam. The traffic could be carried on in exactly the same way, whether steam or electricity was used as motive power, and thus the change could be made without interfering at all with the regular operation of the road.

Hardly anybody doubts that the public would greatly appreciate the advantages inherent in electric traction, and the above figures go to show that the change would in the great majority of cases be accompanied also by an increased net revenue for the railroad company.

C. L. DE MURALT.